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DISPERSAL OF GROUND BEETLES (COL., CARABIDAE) IN ARABLE LAND

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SUMMARY

With regard to re-colonisation after hibernating the dispersal of ground beetles from boundary strips into fields was investigated by mark / recapture-experiments. Coloured spots on the pronotum, applicated with a varnish-pen, served as markings. The study was carried out in winter wheat fields near Darmstadt (Hesse, FRG). The marked carabids were released at the boundary strip adjacent to the field and were recaptured in pitfall traps distributed in the field in different distances up to 200 m from the boundary. From 23 000 marked ground beetles the recapture rate was about 9 %.

Carabus granulatus *showed the greatest dispersal activity with 5 from 234 marked specimens recaptured in 200 m distance. They needed an average of 2 weeks to cover this distance.* Agonum dorsale, Pterostichus melanarius *and* Pt. cupreus *were found in distances of at least 150 m with some specimens.* Carabus auratus *and* Agonum mülleri *could be recaptured in distances up to 100 m. The results indicate that most field carabids are able to re-populate fields up to a width of about 300 m, as long as they are surrounded by adequate marginal biotops.*

An asphalted lane with a width of 3,5 m between two wheat fields was a barrier for all investigated carabid species and reduced their dispersal significantly.

INTRODUCTION

Ground beetles as polyphagous predators are important links of the agro-ecosystem. Several studies have shown the significant role of carabids in reducing pest insects, e.g. aphids in cereal fields (EDWARDS et al. 1979, SCHELLER 1984, SUNDERLAND et al. 1987, CHIVERTON 1987a). Many adult-overwintering carabids like *Agonum dorsale* or *Pterostichus cupreus* hibernate in hedges and boundary strips (uncultivated, preponderant grassy banks adjacent to the fields as defined in GREAVES & MARSCHALL 1987) and re-populate the fields in early spring (DESENDER 1982, WALLIN 1985, KNAUER & STACHOW 1987, WELLING et al. 1990). At the time when the aphid-colonisation of the cereal begins, these species are already occurring in the fields in high densities. Therefore they can contribute to an aphid reduction at an early stage (CHIVERTON 1987b).

Only little is known as to how far carabids spread into the fields from adjacent habitats. COOMBES & SOTHERTON (1987) reported that a small proportion of *Agonum dorsale* marked in boundary strips could be found in the fields in distances up to 200 m. In regard to estimating field sizes that may be desirable from an ecological point of view, the dispersal of ground beetles is an important factor. For this reason, during investigations on the augmentation of beneficial insects in winter wheat (WELLING 1990), the migration of abundant field carabids was studied by means of mark / recapture-experiments.

Central points of the study were:
- How deep by do the ground beetles spread into the fields?
- How much time do they need?
- Does a typical, asphalted lane between two fields act as a barrier influencing the dispersal of the carabids?

MATERIAL & METHODS

The investigations were carried out during May - June 1988 and April - July 1989 in winter wheat fields at Habitzheim near Darmstadt (South Hesse, FRG). In 1988 as experimental site served two facing wheat fields with adjacent field boundaries (0,5 m), divided by an asphalted lane of 3,5 m width (Fig. 1).

Carabids were collected in dry pitfall traps, determined, counted, marked and released the same day. The beetles were marked by a coloured spot on the pronotum applicated with a varnish-pen ("Edding 751 opak"). By using different colours at every release, the intervalls between release and recapture could be determined. The pitfall traps had a diameter of 10 cm, the bottom was covered with straw and small branches as shelter for smaller beetles. To drain off rain water the bottom of the traps had been perforated.

All species that were catched in higher numbers during the trapping period were investigated, both spring-breeders like *Agonum dorsale* and *Pterostichus cupreus* as well as autumn-breeders like *Pterostichus melanarius* (see Table 1).

The marked carabids were released between boundary strip and field. Pitfall traps were placed in distances of 10 m and 20 m around the releasing site in the boundary strips, in the field edges and inside the fields as shown in Fig. 1. With this arrangement both the barrier-effect of the lane and a possible preference for the boundary strip or the field could be determined. In the field adjacent to the releasing site 10 traps were also established in 50 m and 12 traps in 100 m distance. Althogether 118 traps were used.

1989 the investigations were repeated in a neighbouring winter wheat field. This year the main question was how far the carabid beetles would move into the field. Therefore, the number of pitfall traps was raised to 30 respectively for the distance of 50 m and 100 m from the releasing site. 45 traps were established in 150 m and in 200 m distance, respectively. In 1989 202 traps were used.

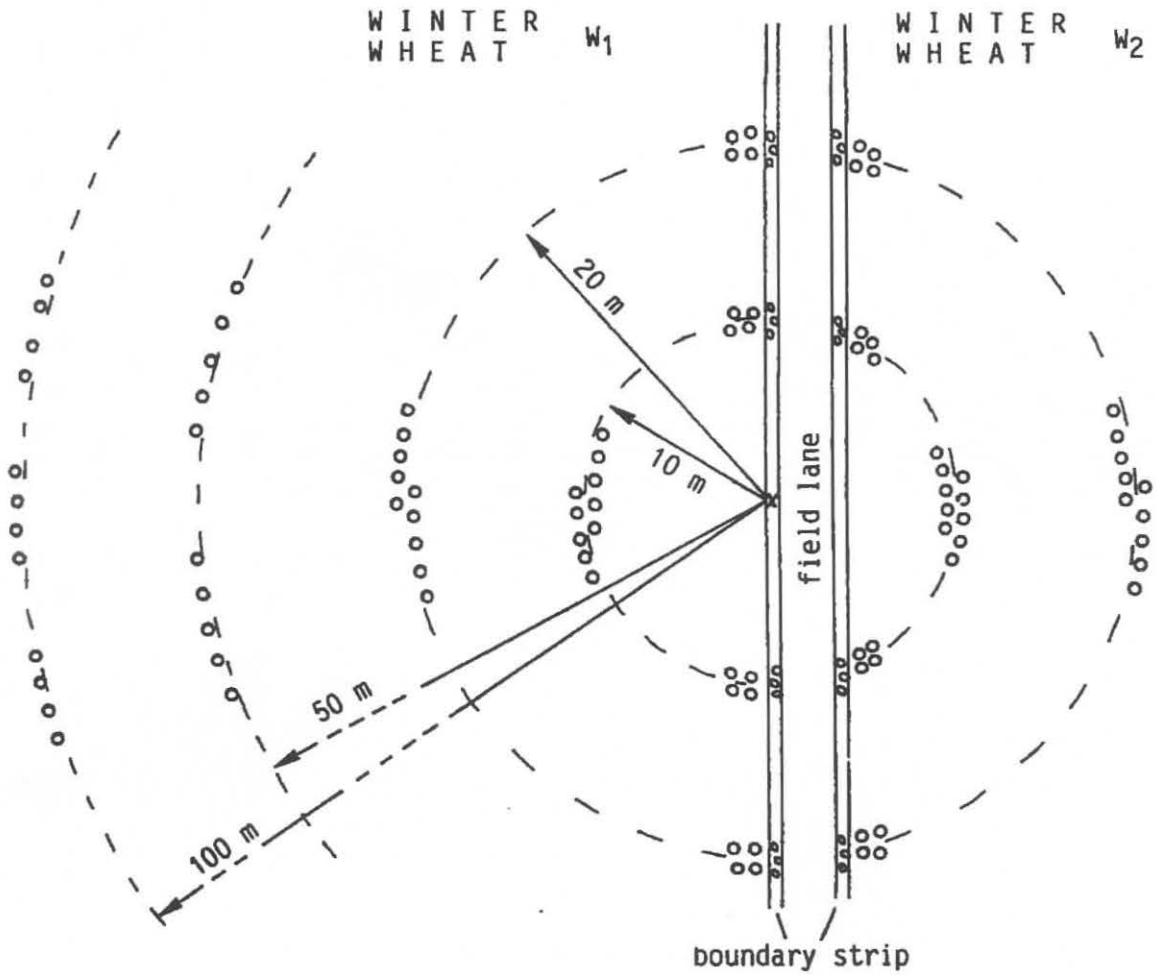

Fig. 1: Distribution of pitfall traps in two winter wheat fields with boundary strips. The fields were divided by an 3,5 m broad asphalted lane. Habitzheim (FRG), 1988. o = pitfall trap, x = releasing site of marked carabids

RESULTS

From 14 305 carabids that were collected and marked in 1988, 1 233 beetles could be recaptured (8,6 %). In 1989 8 886 carabids were marked, the recapture rate was 8,9 % (Table 1).

Barrier-effect of the field lane

In 1988 the recapture rates of marked ground beetles in the 10 m- and 20 m-traps of the wheat fields W_1 (releasing side) and W_2 (opposite side) were compared. Since dry pitfall traps might show individual differences in the catching capacity (carabids may escape by climbing up dirty trap walls or cereal stalks etc.) the quota "marked/unmarked beetles" was formed. These quotas were analysed for every single carabid species using the χ^2-test (Table 2).

Column "a" of this table makes evident that the field lane acted as a barrier for most carabid species, preventing a

Table 1: Numbers of marked and recaptured carabids (Habitzheim, FRG)
2.5. - 16.6.1988 using 118 pitfall traps
17.4. - 7.7.1989 using 202 pitfall traps

	1988			1989		
	marked	recaptured	%	marked	recaptured	%
Carabus granulatus	886	181	20,4	234	97	41,5
Carabus auratus	622	178	28,6	47	32	68.1
Carabus nemoralis	193	36	18,7	50	8	16,0
Loricera pilicornis	1.033	39	3,8	268	75	28,0
Harpalus rufipes	108	5	4,6	128	5	3,9
Harpalus aeneus	235	7	3,0	522	31	5,9
Pterost. cupreus	252	38	15,1	947	329	34,7
Pterost. melanarius	793	66	8,3	452	23	5,1
Agonum mülleri	1.049	119	11,3	42	2	4,8
Agonum dorsale	9.013	556	6,2	4.497	129	2,9
Amara sp.	121	8	6,6	1.699	64	3,8
Σ	14.305	1.236	8,6	8.886	795	8,9

Table 2: Column a: Distribution of unmarked (unm.) and marked (m.) carabids in two winter wheat fields that are divided by a field lane. Habitzheim (FRG), 1988.
** = significant ($\alpha = 0,05$),*
*** = highly significant ($\alpha = 0,01$)*
Column b: Relation of recaptured carabids from wheat field W_1 (field adjacent to releasing site) and W_2 (field on the other side of the lane).

	a			b
	field W_1 unm./m.	field W_2 unm./m.	difference significant	relation W_1 : W_2
Carabus granulatus	334/131	233/46	**	1 : 0,36
Carabus auratus	218/142	162/31	**	1 : 0,22
Carabus nemoralis	60/24	41/10		1 : 0,42
Pterost. cupreus	95/22	131/15	*	1 : 0,67
Pterost. melanarius	421/52	306/15	**	1 : 0,29
Loricera pilicornis	327/33	515/7	**	1 : 0,21
Agonum mülleri	420/93	329/24	**	1 : 0,26
Agonum dorsale	3937/446	2851/92	**	1 : 0,20

homogeneous distribution over both fields with high significance ($\alpha = 0,01$). Only for *Carabus nemoralis* could the difference not be proven significantly, although the tendency was the same. *C. nemoralis* occurs mainly in hedges, forest edges, gardens etc. and is no typical field carabid.

Column "b" shows the relation of recaptured ground beetles from field W_1 to field W_2. The smaller species *L. pilicornis*, *A. mülleri* and *A. dorsale* were more influenced by the barrier-effect of the lane (mean relation $W_1 : W_2 = 1 : 0,223$) than the middle sized species *Pt. cupreus* and *Pt. melanarius* (mean relation $W_1 : W_2 = 1 : 0,480$) and the big species of the genus *Carabus* (mean relation $W_1 : W_2 = 1 : 0,333$).

Spatial distribution in the field

Table 3 indicates, how deep by the carabids spread from the releasing site at the field border into the wheat field. *Carabus granulatus* proved to be the species with the highest migration activity. In 1989 six from 234 marked specimens could be recaptured in 150 m and five in 200 m distance. *Pterostichus melanarius* (452 specimens marked) and *Agonum dorsale* (4 497 specimens marked) were also found in 200 m, but only with one specimen respectively. In 150 m distance we recaptured one marked *Pterostichus cupreus* and one marked *Amara* sp.. *Carabus auratus* and *Agonum mülleri* were found in distances up to 100 m. Distances of at least 50 m were covered by all investigated species.

Due to the distribution of the traps (see Fig. 1) it was possible to evaluate preferences for the different areas "boundary strip", "field edge" and "interior of the field". In respect to the 10 m-traps, nearly all carabid species were recaptured with higher abundance in the boundary strip, although traps were less numerous there. This behaviour was most obvious for *P. cupreus* and *A. dorsale* (for details see WELLING 1990).

Temporal distribution

In regard to the time the carabids needed to cover the various distances, no differences were ascertainable between the 10 m-, 20 m- and 50 m-traps. The likely reason is the relative long lasting interval between controlling the pitfall traps (3 days). To cover the traps situated in wider distances, carabids needed a significantly longer time. For example it took *Carabus granulatus* 7,4 days ($n = 3$) to reach the distance of 100 m and 13,4 days ($n = 5$) to reach 200 m in 1989 (Table 3). Fig. 2 shows, how much time the abundant species *C. granulatus*, *Pt. cupreus*, *Pt. melanarius* and *A. dorsale* needed to cover the various distances. Regarding those data a correlation between species size and velocity of distribution is not obvious.

Some points that are conspicuous: One specimen of *Agonum dorsale* covered the distance of 100 m in 4 days (1988), one specimen of *Carabus granulatus* and of *C. auratus* needed only 2 days for the same distance (1989).

In addition, the time was surveyed, which the carabids needed to cover same distances in the various field areas

Table 3: Number of carabids recaptured in a wheat field in various distances from the boundary strip (releasing site).
Habitzheim, 2.5. - 16.6.1988 und 17.4. - 7.7.1989
n: number of recaptured specimens
d: mean of days to cover the distance
s: standard deviation

distance		10 m		20 m		50 m		100m		150m	200m
year		'88	'89	'88	'89	'88	'89	'88	'89	'89	'89
Carabus granulatus	n:	21	16	28	7	2	12	3	17	6	5
	d:	7,8	6,4	6,5	4,4	6,3	5,0	7,3	7,4	13,3	13,4
	s:	3,5	5,2	3,7	2,6	4,6	2,6	3,8	3,0	4,5	5,3
Carabus auratus	n:	25	3	19	6	6	3	-	8	-	-
	d:	4,7	3,7	6,1	5,5	9,3	10,3	-	4,8	-	-
	s:	2,3	2,1	3,7	2,9	3,9	2,3	-	2,0	-	-
Carabus nemoralis	n:	6	-	5	-	2	1	-	-	-	-
	d:	6,0	-	3,2	-	12,3	1,0	-	-	-	-
	s:	4,1	-	0,8	-	0,4	-	-	-	-	-
Loricera pilicornis	n:	5	2	4	6	1	4	-	-	-	-
	d:	4,2	11,0	5,0	6,3	6,0	8,5	-	-	-	-
	s:	1,6	7,1	3,5	3,9	-	3,0	-	-	-	-
Harpalus *aeneus*	n:	1	5	-	1	-	3	-	-	-	-
	d:	3,0	3,0	-	2,0	-	6,0	-	-	-	-
	s:	-	1,9	-	-	-	1,0	-	-	-	-
Pterost. cupreus	n:	1	39	2	19	2	32	-	16	1	-
	d:	8,0	4,1	6,8	5,7	6,8	6,9	-	9,4	15,0	-
	s:	-	2,7	3,9	6,0	3,9	4,2	-	3,5	-	-
Pterost. melanarius	n:	9	2	2	1	1	2	-	2	1	1
	d:	3,9	11,5	4,0	6,0	6,0	9,0	-	11,5	11,0	15,0
	s:	3,0	7,8	0,0	-	-	3,9	-	0,7	-	-
Agonum müller i	n:	18	-	5	-	1	-	1	-	-	-
	d:	6,4	-	9,3	-	10,0	-	13,0	-	-	-
	s:	4,0	-	6,6	-	-	-	-	-	-	-
Agonum dorsale	n:	88	15	28	15	11	11	7	5	1	1
	d:	4,5	5,4	5,6	5,1	8,7	5,3	6,8	11,6	7,0	9,0
	s:	2,8	4,7	3,7	2,5	3,8	3,0	2,1	3,6	-	-
Amara sp.	n:	-	5	-	4	-	3	-	-	1	-
	d:	-	7,8	-	4,8	-	6,3	-	-	11,0	-
	s:	-	1,6	-	3,6	-	3,2	-	-	-	-

(boundary strip, field edge and interior of the field). Surprisingly most carabid species reached the 10 m-traps and 20 m-traps in the boundary strip earlier than in the interior of the fields. The data for the traps in the field edge were often between those of the boundary strip and the interior. In 1988

Carabus granulatus reached the 10 m-traps in the boundary strip in 5,1 days (n = 30), in the field edge in 5,4 days (n = 20) and in the interior of the field in 7,8 days (n = 21), respectively. The 10m-trap data for *Agonum dorsale* (1989): boundary 4,1 days (n = 31), edge 2,8 days (n = 25), interior 5,4 days (n=15), respectively. Mainly *Carabus granulatus*, *C. auratus* and *Agonum dorsale* showed a quicker dispersal in the boundary strip compared to the interior of the field. More details and a complete data-list for the other species investigated are given in WELLING (1990).

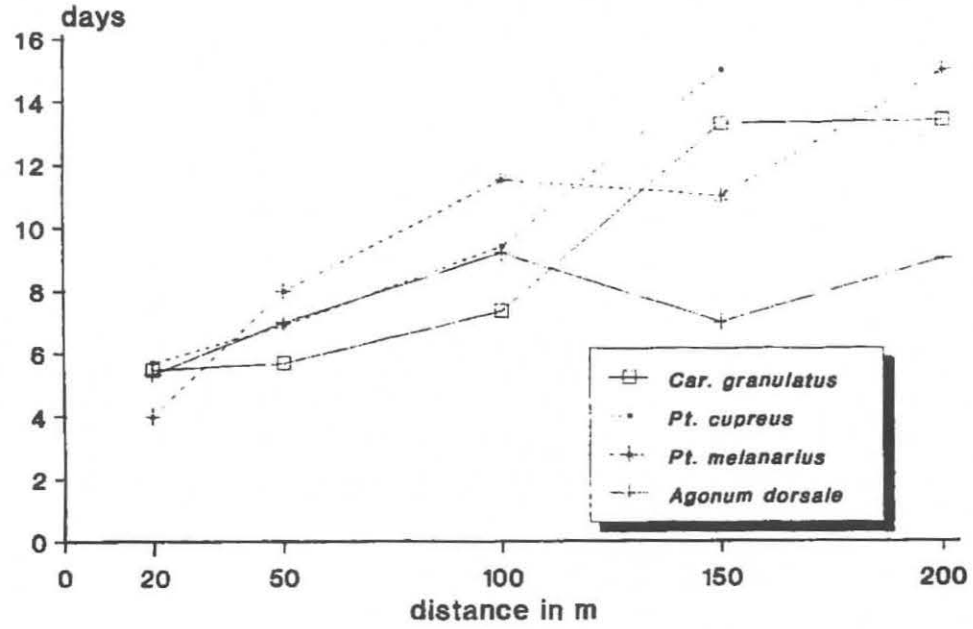

Fig. 2: Migration velocity of four field carabid species in a wheat field. Habitzheim, 1988 and 1989.

DISCUSSION

Many adult-hibernating field carabids that hibernate in non-cultivated habitats immigrate into the crops during their reproductive period in spring / early summer. Also after insecticide treatments a re-population can occur from neighbouring fields or marginal biotopes. This study shows that there are remarkable differences in the dispersal capacity of the carabid species investigated. While *Carabus granulatus*, the most active species in this study, can easily cover 200 m in the field, most other species immigrate about 100 m to 150 m into the fields. So it can be assumed that ground beetles are capable of pervading in fields of a width up to 300 m provided that there are sufficient marginal habitats on both sides. In well structured arable land the colonisation of the fields with carabids does not seem to be limited by the migration potency of the ground beetles but by the expanse and quality of non-cultivated marginal biotopes serving as shelter-belts and hibernation sites.

It should be kept in mind that mark / recapture-experiments only give informations about the distance covered and the time

needed. The behaviour of the beetles in the time from release to recapture, e.g. the concrete movement of the beetles while covering a certain distance, cannot be evaluated in this way. MASCANZONI & WALLIN (1987) describe a method of continuous tracing by means of radar.

The asphalted lane between the two wheat fields turned out to be a barrier for all investigated carabids, preventing their homogenous spread into both fields. MADER et al. (1988) proved similar negative effects of field lanes for wolf spiders (Lycosidae). The structure of the asphalt as well as the dark colour that can lead to high temperatures during the day, has negative effects for arthropods. However, during intensivation of agriculture, the portion of field lanes with solid surfaces (asphalt or concrete) being sufficient for weighty agricultural machines, has increased (detailed data for West Germany see MADER et al. 1988). To prevent an increasing isolation of arthropod populations in arable land, alternatives in road-building have to be developed.

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